Assessing The Role Of Small-Scale Physical and Biological Processes

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LONG-TERM GOALS

Our long-term goal is to quantify the interactions between small-scale biological and physical processes within the upper ocean. This project has addressed that goal by examining specific scientific questions that relate the distribution and variability in sub-1m scale bio-optical properties with coincident spatial scales of physical properties.

OBJECTIVES

Our research objectives have focused on the processes that lead to persistent thin layers (20-40cm in thickness) of planktonic vertical structure in coastal environments. Our high-resolution observations of these features (e.g. Cowles et al 1998) have raised many questions about the role of these features in upper ocean trophic dynamics, optical and acoustical signal propagation, and remote sensing. In particular, we have noted striking correlations between thin layers of phytoplankton and small-scale vertical shear. There have also been observations by Holliday et al. (1998) that suggest that zooplankton aggregate on thin layers of phytoplankton. We addressed specific objectives during FY2001 in order to extend these observations and to understand the mechanisms of thin layer formation and persistence. These objectives can be framed as the following questions.

- To what extent is the formation and maintenance of planktonic small-scale structure driven by the vertical gradients in horizontal velocity?

- To what extent are trophic interactions constrained within thin layers of phytoplankton biomass?

- To what exent is thin layer formation and/or maintenance correlated with mesoscale patterns of phytoplankton biomass and physical forcing over the continental shelf?

Our approach to these questions is addressed in the following section.

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14. ABSTRACT
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15. SUBJECT TERMS

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APPROACH

We approached our objectives for FY2001 through a series of ten one-day cruises conducted between May and October 2001. These cruises focused on the extent of thin layer occurrence over the middle of the continental shelf off Newport, Oregon, under a range of forcing conditions. We used our free-fall profiling system to obtain repeated profiles of temperature, salinity, density, small-scale vertical shear in horizontal velocity, along with bio-optical and bio-acoustical measures of plankton biomass. Bio-optical parameters obtained include 9 wavelengths of particulate absorption and beam attenuation (Wetlabs ac-9) along with pigment fluorescence. Bio-acoustical patterns (indices of zooplankton aggregation) were obtained with a 6-frequency acoustics systems (TAPS, BAE Systems) mounted on our free-fall profiler.

Our study site (80m depth, 10 nm from shore) is centered over a moored ADCP that provides 2m vertical resolution of horizontal velocity, and is within the survey area of a CODAR radio frequency array that provides hourly averages (1-km resolution) of surface currents. In addition, we have access to SeaWiFS imagery that can reveal mesoscale patterns in horizontal distributions of phytoplankton biomass over the continental shelf. NOAA meteorological buoys provide wind data.

These linked physical/biological measurements may permit us to define the multi-dimensional parameter space in which thin layers may be found. The efforts to define that parameter space include the collaborative work of several investigators over the past few years, including Dr. Van Holliday, Dr. Percy Donaghay, Dr. Margaret Dekshenieks, Dr. Dian Gifford, Dr. Jan Rines, Dr. Mary Jane Perry, Dr. Sally MacIntyre, Dr. Alice Alldredge, and Dr. J. Ronald Zaneveld. This group continues to work to refine our understanding of small-scale processes by asking these questions:

- What range of conditions permit thin layer formation and persistence?
- What are the dominant processes that create and maintain small-scale structure?
- Over what time scales do features form, change, or disappear?
- Are particular coastal and oceanic habitats more or less likely to possess persistent small-scale features?
- What is the impact of these features on optical and acoustical signal transduction in the upper ocean?
- What is the impact of small-scale features on trophic processes?
- To what extent, and under what conditions, must we alter our sampling strategies to obtain acceptable, if not perfectly accurate, estimates of the distribution of physical, chemical, and biological properties and rate processes in the upper ocean?

WORK COMPLETED

During FY2001 we conducted 10 one-day cruises off the Oregon coast, obtaining over 150 profiles of high-resolution hydrographic, bio-optical, and bio-acoustical data. The addition of the bio-acoustical instrument (TAPS) to our free-fall profiler for this field year gave us new insights into the degree of aggregation of zooplankton on phytoplankton distributions. The data processing and analysis from these cruises is in progress.

We continued our collaboration during FY2001 with other ONR investigators involved in the 1998 East Sound Thin Layers experiments, and we are developing interpretations of these coupled physical/biological processes. We have been involved in the preparation of four manuscripts on small-scale structure during the past year (Cowles and Kosro (in preparation), Dekshenieks et al.(in review), Eisner et al. (in review), Alldredge et al. (in press)).

RESULTS

Small-scale structure over the continental shelf

We obtained a extensive series of vertical profiles on September 5, 6, and 7, 2001 over the mid-shelf. Weak upwelling-favorable winds were present in the afternoons of those days, with relatively calm conditions in the mornings. Surface currents, in response to local wind forcing, showed weak flow to the SW (Figure 1). We observed a strongly stratified upper water column, with sharp gradients in all properties at the base of the shallow mixed layer (Figure 2). The small-scale maxima in fluorescence persisted throughout the day. We also observed local maxima in acoustic backscatter intensity (Figure 3) that suggests aggregation of zooplankton around local maxima in phytoplankton biomass.

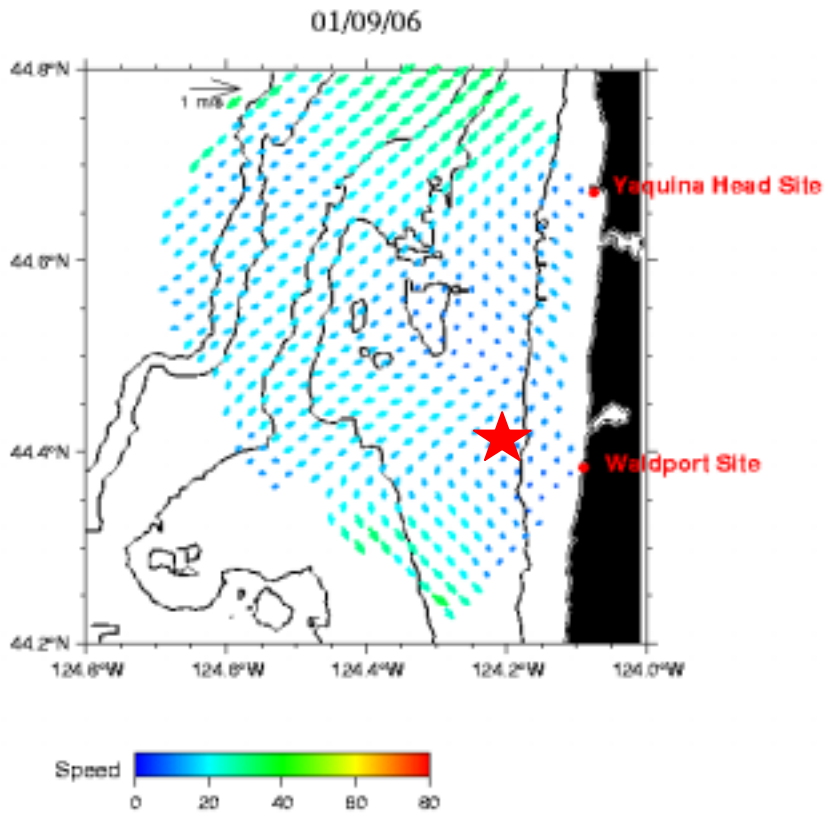

Figure 1. Map of surface currents on September 6, 2001, as estimated from the Oregon State University CODAR system off the central Oregon coast. Velocity vectors over the mid-shelf indicate flows of 10-20 cm s^{-1} to the SW. Note also the cyclonic rotation of the surface flow as it passes over the shallow topography south of our study site (marked with red star).

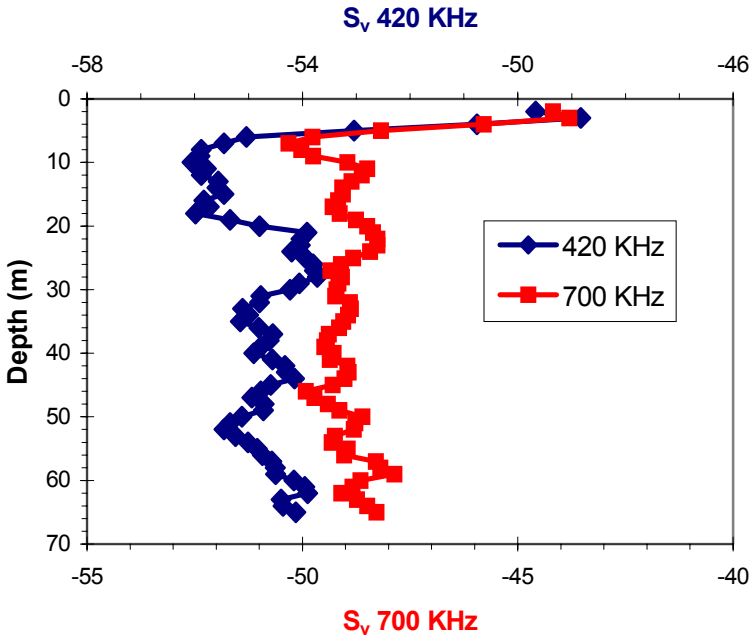

Figure 2. Vertical profile of sigma-t and phytoplankton fluorescence the morning of September 6, 2001, 10 nm west of Newport OR (at study site marked in Figure 1). Note the correlation between steps in sigma-t and the narrow bands of fluorescence at 4m and 7m.

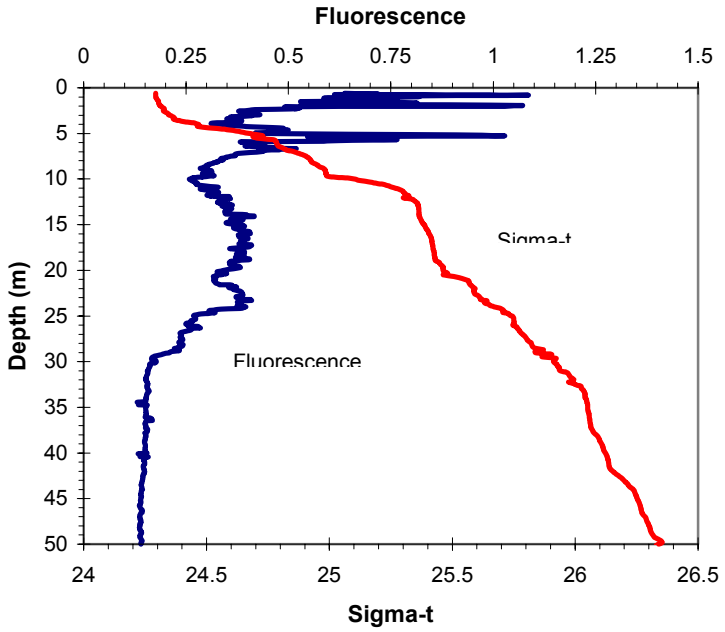

Figure 3. Vertical distribution of acoustic backscatter (S_v) for 420 and 700 KHz frequencies for the profile shown in Figure 2. Note the local maxima in S_v near the fluorescence maximum at 5m depth, suggesting small-scale aggregation of zooplankton on the local maximum in phytoplankton biomass.

IMPACT/APPLICATION

Our results suggest that additional research is needed to document the link between the vertical scales of horizontal velocity changes and patterns of small-scale planktonic structure. It is important to our understanding of plankton dynamics to shift our attention from *vertical* processes to *horizontal* processes. Our work with biological small-scale structure suggests that previous observations of small-scale biological patchiness may not have been observations of stochastic fluctuations in biological structure (i.e., patchiness), but under-sampled observations of persistent, small-scale structure. Centimeter-scale organization of planktonic biomass forces a re-evaluation of water column rate processes, and challenges our existing paradigms for sampling and experimentation over scales of meters and 10's of meters.

TRANSITIONS

The results from repeated sets of profiles from the Oregon continental shelf, along with interpretation of the extensive data set from East Sound Thin Layers Experiment provide new insights into the mechanisms that create that persistent pattern on small-scales. This will be essential for prediction of the impact of persistent small-scale pattern on the attenuation of optical and acoustic signals in the upper ocean. These observational techniques may now be applied at various oceanic study sites, thus extending our appreciation of the role that small-scale processes may play in our estimates of water column production.

RELATED PROJECTS

We have active collaborations with the following ONR Principal Investigators:

Dr. Percy Donaghay, University of Rhode Island
Dr. Jan Rines, University of Rhode Island
Dr. Dian Gifford, University of Rhode Island
Dr. David Smith, University of Rhode Island
Dr. Alice Alldredge, UC Santa Barbara
Dr. Sally MacIntyre, UC Santa Barbara
Dr. Mary Jane Perry, University of Washington
Dr. Van Holliday, Tracor Systems
Dr. J.R. Zaneveld, Oregon State University

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PUBLICATIONS

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PATENTS

None